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EXPERIMENTAL STUDY ON THE THERMOSIPHON SOLUTION ELEVATION PUMP WITH MULTIPLE LUNATE CHANNELS USED IN MINITYPE SOLAR AIR-CONDITIONING SYSTEM

Li Zhengliang¹, Wang Daxi², Zhang Xiang³, Zheng Hongfei³

¹Guangxi Normal College, Nanning City, 530001, China

²Guangxi University of Technology, Liuzhou, 545006, China

³School of Mechanical and Vehicular Engineering, Beijing,
Institute of Technology, Beijing, 100081, China

ABSTRACT

A special structure thermosiphon solution elevation pump with multiple lunate channels used in minitype solar air-condition system was designed and experimentally measured on its elevating effects. Under the determinate operation conditions, its transient state performances were tested. The curves of the temperature and strong solution elevation volume with operating time were given out. Researches indicate that only 20 minutes is required from start-up to steady operation. Under the steady state conditions, the elevating rate of the strong solution and the distilled water yield rate versus the operating temperature were investigated. The minimum start-up operating temperature under different the immersing heights and the weak solution concentration were determined. The experimental results show that under the operating temperature condition of 85 °C, the strong solution elevation rate could reach 32 ml/s for 45% weak solution concentration. If all distilled water is evaporated, the refrigeration capability of the chiller can reach about 9 kW. At the same time, the heat transfer density of the lunate channel wall is about 10.2 kW/m².

1. INTRODUCTION

There is a couple of significance of saving energy and protecting environment for humankind to use the solar energy to drive air-conditioner. The most important characteristic for without-pump LiBr absorption solar chiller is to use the thermosiphon elevation solution pump to replace electric pump[1]. This unit utilizes the thermosiphon elevation solution pump with multiple lunate channels. Due to the special structure of the lunate channels, the superheat of the solution boiling temperature is decreased efficiently. The boiling and elevation of the LiBr solution can be realized under lower heating water temperature[2,3]. This unit has the characteristic of solution elevating amount bigger and more steady than that of the thermosiphon solution elevation pump with single lunate channel[2].

2. OPERATION PRINCIPLE OF UNIT

Schematic diagram of the experimental system is shown in Fig.1. It consists of gas-solution separator, condenser, solution elevating pump, storage solution tank, simulation solar heater and some pipes. The structure and material of the equipments were presented in reference [4].

The operation principle of the unit is: the heating water yielded by simulation solar heater is pumped into the heating tube, in which the heating water heats LiBr weak solution through the outside of the lunate channel. At the same time, another loop heating water is pumped into the inner tube of the lunate channel from its bottom end, in which the heating water heats LiBr weak solution through the inside of the lunate channel. So, LiBr weak solution is heated from two sides (outer and inner tube). The weak solution enters the elevating channel from the bottom of the storage solution tank, in which it is heated continuously until boiling and changed into two phase liquid. And then, forced by the weight pressure coming from the solution in storage solution tank, the solution is elevated into gas-solution separator to change the strong solution. The vapor goes into the condenser, in which it is condensed to change stilling water. The stilling water and the strong solution together go into the storage solution tank through different pipes and meters, separately, as shown in Fig. 1.

3. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental conditions: the pressure range of unit is 4—6kpa, the input temperature of the cooling water is 17 °C, the flow rate of the cooling water is 0.2kg/s, the heating water flow rate is 0.3kg/s, ambient temperature range is 20~22 °C.

3.1 Transient State Performance Test

Transient state performance of unit is that characteristic during which unit operates from starting up until steady state operation. It is an important index to reflect the heat mass of unit. Under the determinate conditions, some parameters versus operating time were tested when the unit transient state operate. During the test, the heating water temperature was 80⁰C. The immersing height of the weak solution was 650mm.

The input and output temperature of the heating and cooling water versus operating time are shown in Figs. 2 and 3. The elevating rate of the strong solution and the stilling water yield rate versus operating time is shown in Fig. 4. The experimental results indicate that the output temperature of the heating and cooling water have remarkable change from start-up until steady state operation. Only 5 minutes, a litter solution and stilling water is elevated to gas-solution separator. Their yield rate fleetly increases with the operating time, as shown in Fig. 4. After 20 minutes, the solution elevating rate and stilling water yield rate slowly go up to steady. At this time, the output temperature of the heating and cooling water also go up to steady.

3.2 Steady State Performance Test

Steady state performance of the unit is an important index to indicate elevating ability. It is also an important basis to instruct the optical design and utilization of the unit. So, the steady state

experiments about parameters having influence on the solution elevating rate and distilled water yield rate had been carried out.

3.2.1 Influence of the Operating Temperature on the Solution Elevating Rate

The heating water temperature is the operating temperature. The solution elevating rates versus the operating temperature are shown in Fig.5. The immersing height of the weak solution was 650mm in the test. The elevating pump can not operate if the operating temperature is extremely low. The start-up operating temperature of the unit is about 76~78 °C when the concentration of LiBr solution is 45%. If the concentration of LiBr solution is 40%, then the start-up operating temperature of the unit is decreased to 71~72 °C.

The experimental results shown in Fig. 5 indicate that the operating temperature has notable influence on the elevating rate of the solution. The elevating rate of the solution freely increases with the operating temperature.

It can be found from the experiments that the elevating rate of the strong solution is about 30ml/s when the weak solution concentration is 45% and the heating water temperature is 80 °C. In this time, the distilled water yield rate is about 3.8g/s. If the distilled water is evaporated completely (evaporation temperature is 7 °C), the refrigeration ability can reach 9kw. It is shown that this pump has corking elevating ability. Based on the experimental results, the heat transfer density through the lunate channel wall can be calculated also. Supposing, A is the area of the channel wall, m^2 . ΔT is the temperature difference between input and output of the heating water. M_f is the flow rate of the heating water. Then, the total heat energy provided by the heating water is,

$$Q = M_f c_p \Delta T = 0.3 \times 4.18 \times 8.5 = 10kW$$

where c_p is the specific heat of water. It is known that $A=0.256m^2$, where A is the total area of the lunate channel inner tube and outer tuber wall. If heat loss in other components is ignored, the heat transfer density through the lunate channel wall can be calculated as follow,

$$q = \frac{Q}{4A} = 10.2kW/m^2$$

It is found that the heat transfer density through the lunate channel wall is very big.

3.2.2 Influence of the Immersing Height of the Weak Solution on the Start-up Temperature

Immersing height of the weak solution is the height from the bottom of the channel to the surface of the weak solution in channel when unit do not operate. Immersing height of the weak solution has remarkable influence on the solution elevating rate. If the immersing height is too low, the solution can not be elevated to the gas-solution separator. In fact, there is a coincidence relation among the immersing height, solution concentration, operating temperature and operating pressure. In order to know the immersing height influence on the performance of the thermosiphon solution elevation pump with multiple lunate channels. Some especial tests with

different immersing height have been completed. In the tests, the weak solution concentration is 40%, 45% and 50%, respectively. The experimental results is shown in Fig. 6.

It can be found from Fig.6 that the immersing height has remarkable influence on the start-up temperature. If the immersing height increases, the start-up temperature will decrease.

4. CONCLUSIONS

- (1) The experimental results show that this pump has the notable advantages of lower start-up temperature and wider range of operating temperature and more steadily running than that with other figure of channels because of the solution heated through double directions and the superheat degree decreased by the enhanced heat transfer of the narrow slot.
- (2) Operating temperature has remarkable influence on solution elevating rate and distilled water yield rate. It has not good effect until operating temperature over 80°C for 45% weak solution concentration. If the weak solution concentration is 40%, it will have good effect when operating temperature is about 75~80°C.
- (3) There is a coincidence relation among the immersing height, solution concentration, operating temperature and operating pressure. When solution concentration and operating pressure are determinate, the immersing height of the weak solution has remarkable influence on the start-up temperature. In general, when the immersing height increases 60~80mm, the start-up operating temperature will decrease about 1°C.

5. ACKNOWLEDGEMENT

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Figure 21

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6